International Journal of Plant Production (2020) 14:549–569
https://doi.org/10.1007/s42106-020-00108-2

REVIEW

Pulses Production in Pakistan: Status, Constraints and Opportunities

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Received: 11 April 2020 / Accepted: 2 July 2020 / Published online: 6 July 2020

Abstract

Pulses are smart crops both for humans and the cropping system as they provide protein, minerals, vitamins, and fiber for human diet and nitrogen to the soil and contribute to the maintenance of biodiversity. Pulses, also called grain legumes, contribute about 33% of the global dietary protein requirement of the human population. In Pakistan, the production of pulses is far less than the requirement and the balance is met through imports. The reasons for low production and yield of pulses, in Pakistan, include lack of innovative crop improvement programs and seed distribution system. Currently, about 80% of the pulses are cultivated from the farmers own saved seed. Other major factors responsible for low production and yield are abiotic (drought, heat, salinity) and biotic (weeds, diseases, and insect-pests) stresses, and factors related with soil (marginal lands, alkaline soils with low organic matter and erosion), climate change, lack of crop-specific farm machinery, post-harvest losses and marketing issues. This manuscript discusses the current status, constraints, and opportunities to improve the production of pulses to meet the national requirements. The major opportunities to improve the pulses production includes crop improvement (development of short duration, high yielding, disease resistant and climate resilient varieties), intercropping and growing of pulses as catch crop, adoption of conservation agriculture to conserve the resources, strengthening system of certified seed distribution, provision of crop-specific farm machinery, development and dissemination of site-specific production technologies and seed enhancements.

Keywords Pulses · Dietary protein · Nitrogen fixation · Seed enhancement · Conservation agriculture

Introduction

Pulses are grain crops from the family Fabaceae. These provide a cheaper source of dietary protein for the masses (Aguilera et al. 2013) and play a significant role in agricultural ecosystems by fixing the nitrogen symbiotically (Siddique et al. 1999; Rubiales and Mikic 2015). Worldwide, legumes occupy 12–15% of arable land to produce 27% of total crop production and provide 33% of dietary protein (Mishra et al. 2014). Being a rich source of protein, legumes are a dietary staple for millions of humans and animals.

The year 2016 was declared as International Year of Pulses by United Nations and pulses were announced as nutritious seeds for a sustainable future (FAO 2016). However, pulses are grown as secondary crops and the global area under cereals is about ten times higher than that of pulses (Cernay et al. 2016). The average consumption of pulses in the world is 7 kg/person/year (https://www.fao.org/pulses-2016). In Pakistan, pulses are grown on 5% of the total cropped area (NARC 2017) and more than 60% of the produce is utilized by the human population with an average consumption of 4.18 kg/person/year (self-calculated).

Major pulse crops cultivated in Pakistan include chickpea (*Cicer arietinum* L.), mungbean [*Vigna radiate* (L.) Wilczek], lentil (*Lens culinaris* Medic.) and mashbean (*Vigna mungo* L. Hepper). Other minor pulses are cowpea [*Vigna unguiculata* (L.) Walp.], pigeonpea (*Cajanus cajan* L. Millsp.), common bean (*Phaseolus vulgaris* L.), moth bean [*Vigna aconitifolia* (Jack) Merechal] and faba bean (*Vicia*

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s42106-020-00108-2) contains supplementary material, which is available to authorized users.

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faba L.) (NARC 2017). The protein contents in grains of pulses range from 15 to 30% (Hall et al. 2016). Specifically, protein contents range between 17–19% in chickpea (Cai et al. 2002; Sreerama et al. 2012), 23–31% in lentil (Fouad and Rehab 2015; Ghumman et al. 2016), 21–31% in mungbean (Anwar et al. 2007) and 21–28% in mashbean (Kole et al. 2002). Pulses can help restore degraded soils through biological nitrogen fixation, mobilization of nutrients as phosphorus, increasing organic matter through root biomass and leaf fall, and protecting soil from erosion with cover and promoting the formation of soil aggregates through deeper root systems (Venkateswarlu et al. 2007; Ganeshamurty 2009).

Production of pulses in Pakistan is 0.7 Mt while the total requirement (consumption) is about 1.5 Mt. To meet the requirement, Pakistan has to import 0.8 Mt pulses every year (chickpea, lentil, mungbean and mashbean) mostly from Canada, USA, Australia, China, Russia, Ukraine and Africa (https://www.dawn.com/news/1446931, Accessed 10 September 2019). Production and area statistics of major pulses during the last 5 decades are given as Fig. 1 whereas national requirements, production, and the deficit of major pulses during the last three decades are given as Fig. 2. In the year 2017, Pakistan imported 1.23 Mt (952 M$) pulses, while in 2018 imports were 0.724 Mt (535 M$) with 41% decrease in quantity and 44% in the value (https://www.pbs.gov.pk/content/external-trade-statistical-data-8-digit-level-year-2010-2011-2017-2018, Accessed 20 September 2019). The import of pulses during the last three decades is given as Fig. S1. To bridge the demand and supply gap, an ACIAR (Australian Center for International Agricultural Research)-funded project aimed to enhance the production of pulses (mainly chickpea and lentil) and profitability of pulses is in progress (https://aciar.gov.au, Accessed 15 November 2019).

The main reasons of low yield of pulses in Pakistan include, lack of crop improvement and seed distribution system, abiotic stresses (drought, heat stress, salinity, and chilling stress), biotic stresses (weeds, disease, and insect-pests), and soil related issues such as cultivation on marginal soils which have high pH, low organic matter, low moisture, and high erosion. Moreover, pulses are considered minor crops in Pakistan and are substituted with major crops (cereals) resulting in decrease in area under pulses and the total production. Furthermore, changing climate (frequent drought episodes, heat waves, erratic rainfall and shift of season), lack of farm machinery (for sowing, irrigation, plant protection, and fertilizer application), post-harvest losses, and marketing (no-support price) constraints are also bottleneck in getting required production in pulses.

In Pakistan, the production of pulses is centered in two regions, (i) Thal desert (spanning through districts Jhang, Bakhar, Khushab, Mianwali, and Layyah) and (ii) Barani region (including districts Attack, Chakwal, Jhelum, Rawalpindi and Narowal). In both above production regions, success of crops relies on the incidence of rainfall. There is a decreasing trend in area and production of chickpea, lentil, mungbean and mashbean since last five decades (Figs. 3, 4, 5, 6) owing to disease infestation, insect-pests, marketing

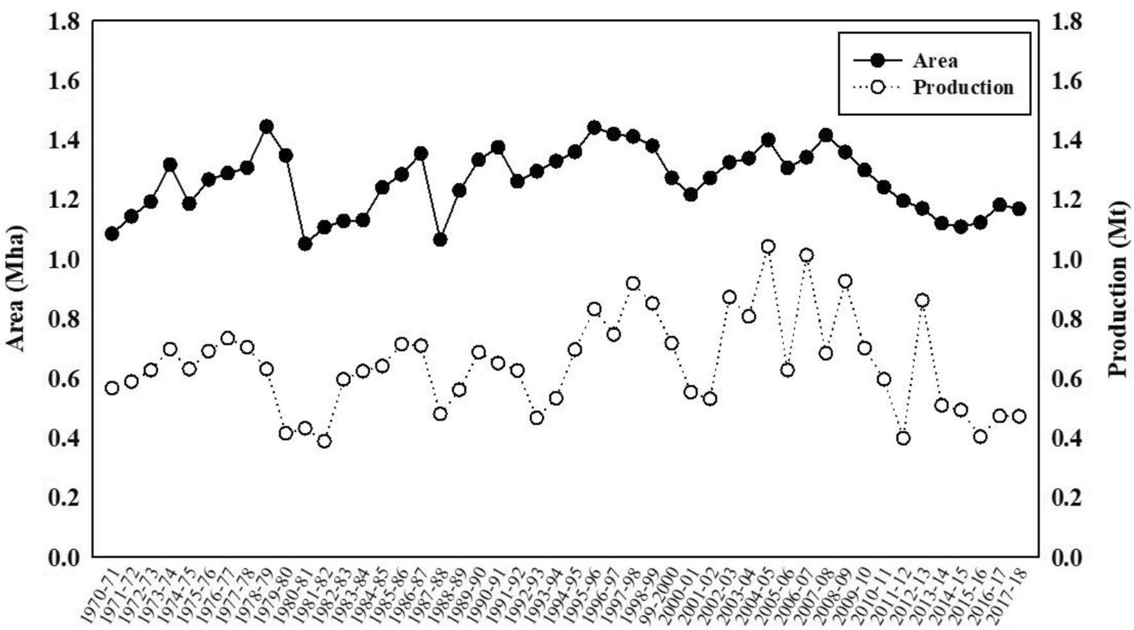

Fig. 1 Area and production statistics of major pulses (chickpea, lentil, mungbean and mashbean) during last 5 decades in Pakistan. Source: https://www.pbs.gov.pk

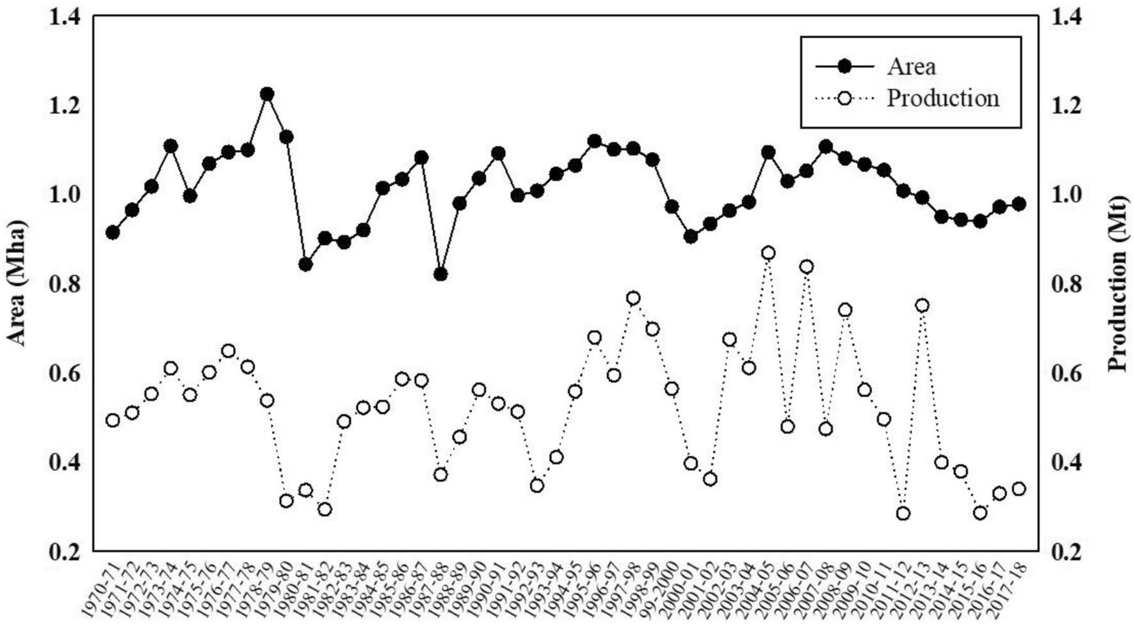

Fig. 2 Area and production statistics of chickpea during last 5 decades in Pakistan. Source: https://www.pbs.gov.pk

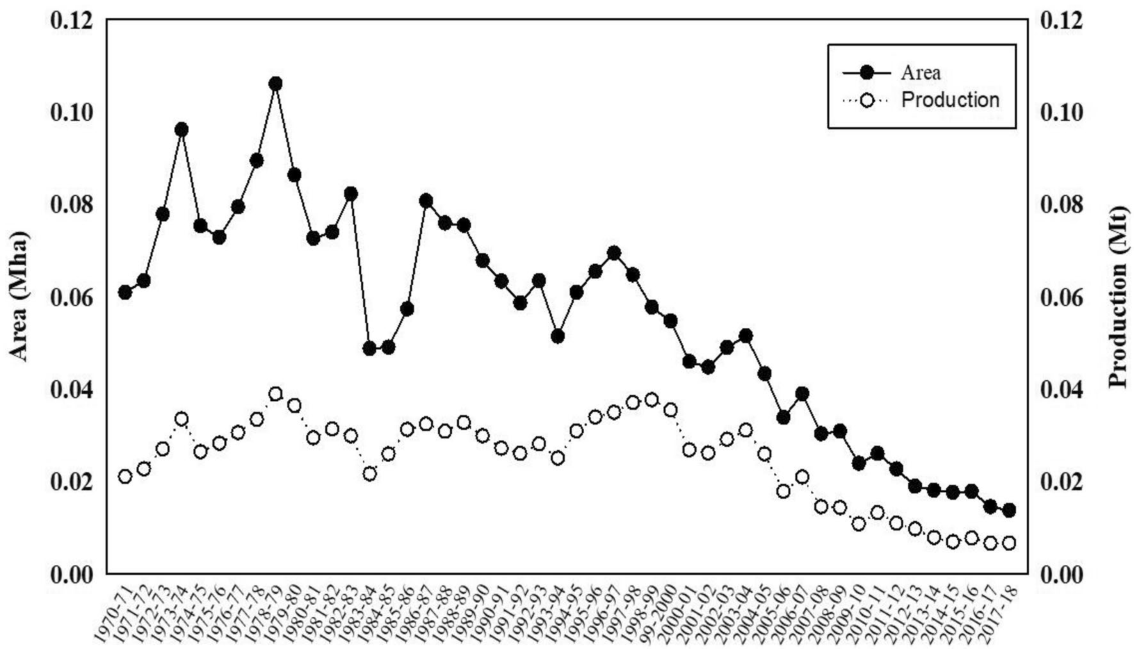

Fig. 3 Area and production statistics of lentil during last 5 decades in Pakistan. Source: https://www.pbs.gov.pk

problems, lack of crop-specific farm machinery, changed precipitation patterns, heat waves, and low productivity. Farmers prefer growing wheat (*Triticum aestivum* L.), cotton (*Gossypium hirsutum* L.), and other crops due to high yield potential and better economic returns than the pulses.

There exist opportunities to increase pulses production to meet the required national needs. Crop improvement (developing early maturing, drought, heat, and diseases resistant varieties) is the most promising option in this regard. Increase in the area under pulses, through growing of pulses as intercrop and catch crops (horizontal approaches), seed enhancement, and development and dissemination of site-specific package of production technologies (vertical approaches) can also help to enhance the production.

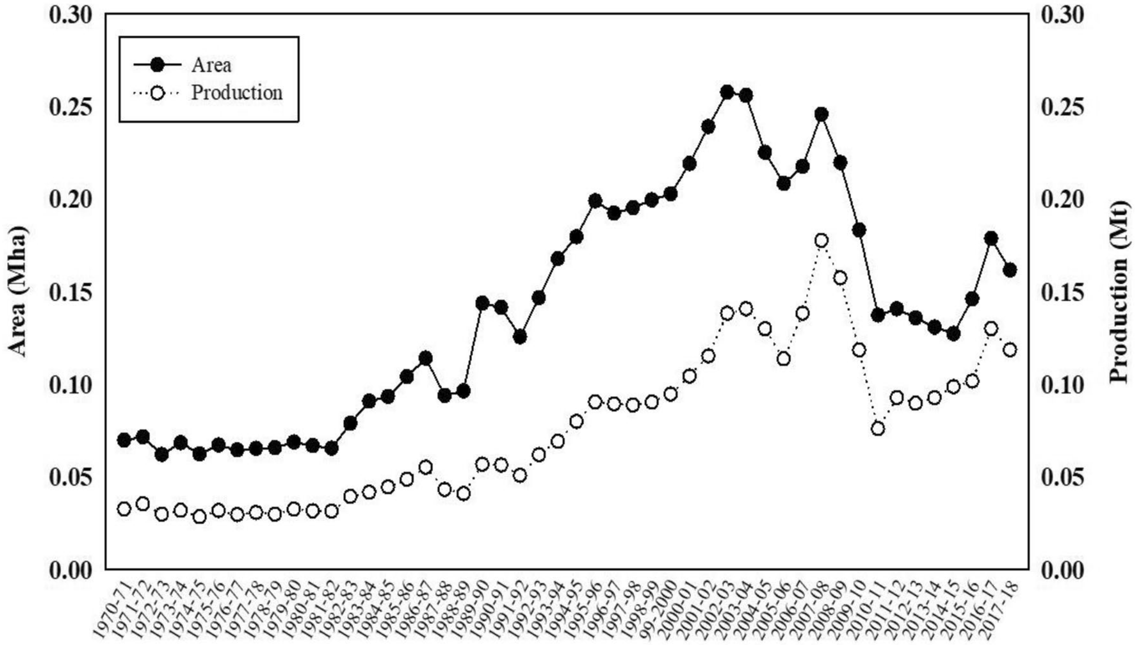

Fig. 4 Area and production statistics of mungbean during last 5 decades in Pakistan. Source: https://www.pbs.gov.pk

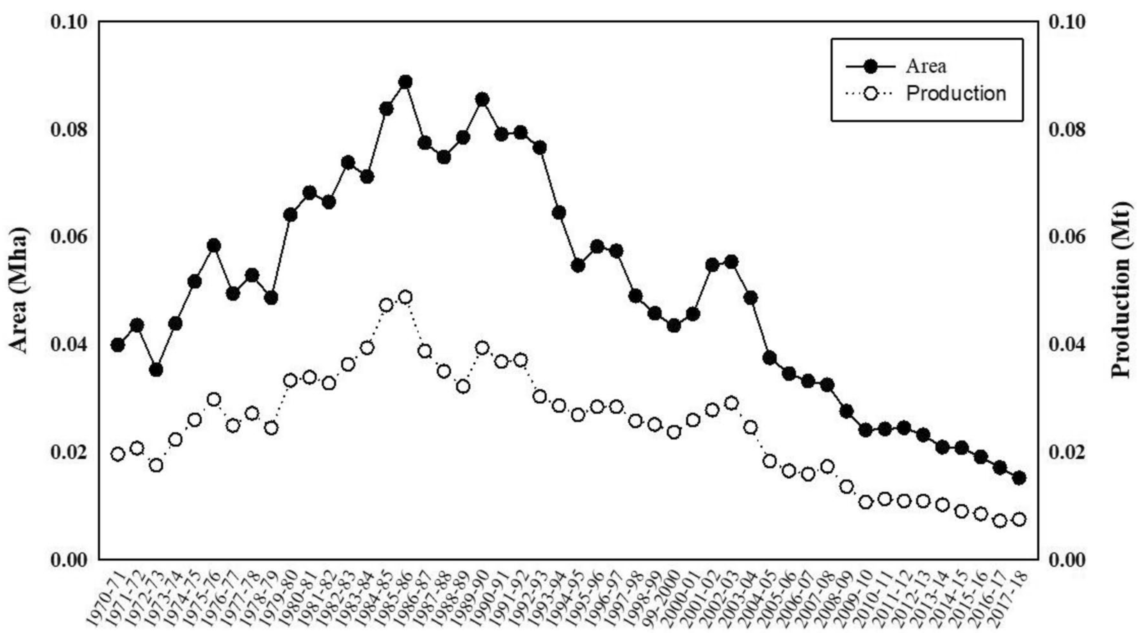

Fig. 5 Area and production statistics of mashbean during last 5 decades in Pakistan. Source: https://www.pbs.gov.pk

Moreover, some initiatives from the Government such as the provision of support price and strengthening of the marketing system, credit facilities to purchase farm machinery, distribution of improved seed, and adoption of conservation agriculture can help to bridge the national requirement gap in pulses.

To the best of our knowledge, there is no comprehensive review on the status, production constraints, and opportunities of increasing production of major pulses in Pakistan. In this review, the current status of production of pulses has been discussed, production constraints have

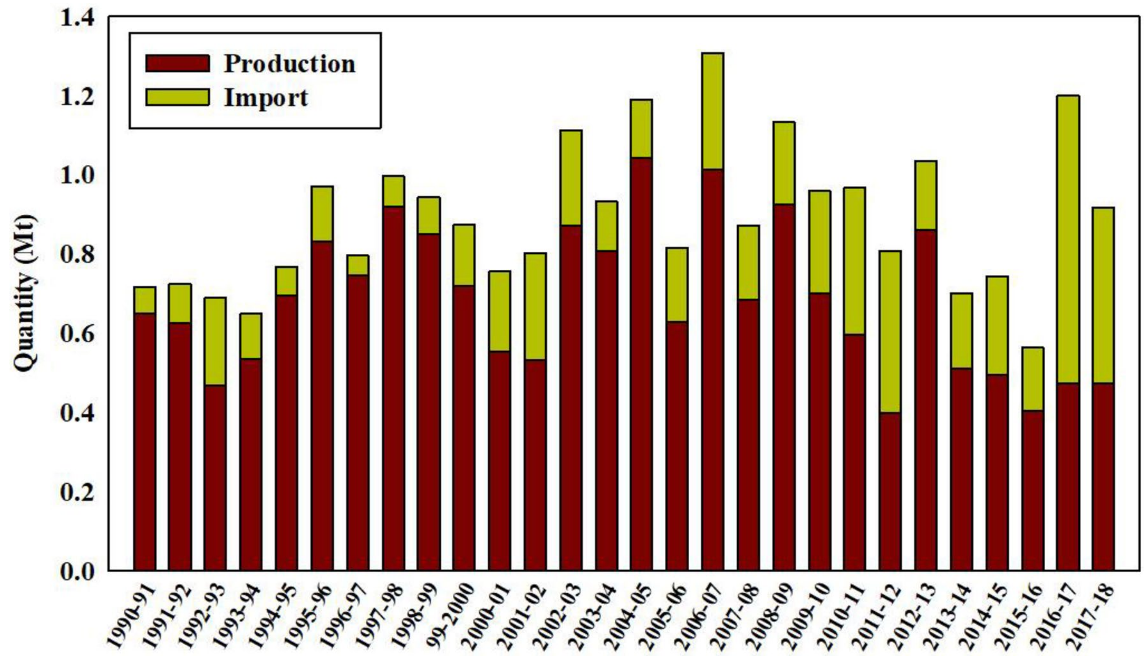

Fig. 6 Pulses (mainly chickpea, lentil, mungbean and mashbean) production status, import/deficit and total requirement of the country of last 3 decades. Source: https://www.pbs.gov.pk

been highlighted and opportunities to enhance the production and productivity of pulses are proposed.

Current Status

In Pakistan, pulses are planted in an area of 1.5 Mha. Among these, chickpea is a major winter pulse crop and mungbean is the principal summer pulse crop. Chickpea occupies (73%) of the total area under pulses with 76% of the total production whereas mungbean contributes 16% of total production from 18% of the area under pulses (Fig. 7). However, each lentil and mashbean is cultivated on 5% of the area under pulses and contribute 5% to the total production (Fig. 7; NARC 2017).

Chickpea

Chickpea is the major pulse crop of Pakistan and is grown on 73% of the area under pulses. Thal desert is home to chickpea production as none of the other crops can be profitably grown in this region due to low fertility, and lack of irrigation water. However, chickpea produces fair yield under moisture stress in marginal lands of Thal desert (NARC 2017). There has been significant yield instability in this region due to drought stress, and infestation of diseases like chickpea wilt, and chickpea blight. The average chickpea yield during last 5 decades (1970–1980, 1981–1990, 1991–2000, 2001–2010 and 2011–2019) was 501, 616, 636, 678 and 670 kg ha^{-1}, respectively (Fig. 3). Although Pakistan is the third largest producer of chickpea after India and Australia (FAO 2014), its production is less than the national requirements. Chickpea imports during the last three decades are given as Fig. S2.

Lentil

Lentil is the 2nd major winter pulse crop of Pakistan. It is cultivated in 5% of the area under pulses (NARC 2017). Rust and blight are the major diseases restricting lentil yield in Pakistan. The average lentil yield during last five decades (1970–1980, 1981–1990, 1991–2000, 2001–2010 and 2011–2019) was 307, 449, 526, 554 and 545 kg ha^{-1}, respectively (Fig. 4). Lentil imports during the last three decades are given as Fig. S3.

Mungbean

Mungbean is the major summer pulse of Pakistan. About 88% area under mungbean is in the Punjab province which produces 85% of total production in the country. Major production constraints of mungbean include pathogen attack, weeds infestation, insect-pest attack, and inadequate supply of certified seed (NARC 2017). Mungbean Yellow Mosaic Virus (MYMV) is the most destructive viral disease in Pakistan. Disease infestation delays maturity, which reduces

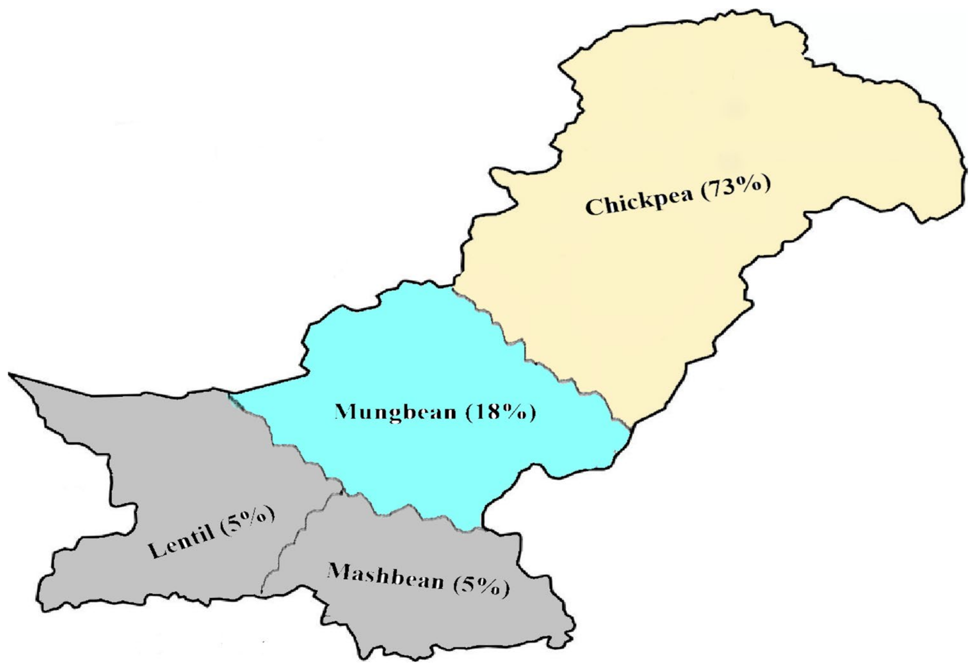

Fig. 7 Current status of pulses grown in Pakistan with their area contribution

the flowering and pod formation (www.nia.org.pk/gin%20mungbean.html, Accessed 19 September 2019). The average yield of mungbean, in Pakistan during last five decades (1970–1980, 1981–191990, 1991–2000, 2001–2010 and 2011–2019) has been 465, 498, 518, 597 and 598 kg ha^{-1}, respectively (Fig. 5). The import of mungbean over the last three decades is given as Fig. S4.

Mashbean

Mashbean is 2nd major pulse crop of the summer season in Pakistan. It is cultivated in 5% of the area under pulses and contributes 5% to the total pulses production in the country. The major reasons for low yield of mashbean include its cultivation on marginal lands, lack of high yielding varieties, and lack of improved production technology. Average yield of mashbean during last five decades (1970–1980, 1981–1990, 1991–2000, 2001–2010 and 2011–2019) remained 479, 565, 610, 636 and 676 kg ha^{-1}, respectively (Fig. 6). However, production is less than the national requirements. Mashbean imported during the last three decades are given as Fig. S5.

Other Pulses

Some other pulses as moth bean [*Vigna aconitifolia* (Jack) Merechal], pigeonpea (*Cajanus cajan* L. Millsp.), common bean (*Phaseolus vulgaris* L.), cowpea [*Vigna unguiculate* (L.) Walp.], and faba bean (*Vicia faba* L.) are also grown in Pakistan, but on a small area. The summer pulses are grown on an area of 3.5×10^{-3} Mha with the production of 2.7×10^{-6} Mt while, winter pulses cover an area of 4.0×10^{-4} Mha with the production of 2.0×10^{-6} Mt (https://www.pbs.gov.pk).

Constraints and Challenges

Crop Improvement and Seed Distribution System

Seed improvement and replacement rate in pulses are not still achieved to the desired level and farmers are forced to use their own saved seed. During 2018–2019, the total requirement of certified seed in the country was 42,674 metric tons while the total seed availability was 1,401 metric tons (from this 10 metric tons was contributed by the public sector while 1,391 metric tons were provided by the private sector) (www.federalseed.gov.pk, Accessed 01 January 2020). This is one of the major reasons for low yield of pulses in Pakistan. The availability of improved varieties of major pules is very low (Table 1). From 1947 to date, 44 varieties of chickpea, 25 varieties of mungbean, 14 varieties of lentil, and 10 varieties of mashbean have been released for commercial cultivation during the last seven decades (Table 1). A recent study indicated that, among the available varieties, chickpea genotypes Bittle 2016, Chattan and Dasht are the most yielding while in lentil, genotypes NIAB Masoor 2002 and Markaz-09 are the best yielder (https://aciar.gov.au, Accessed 15 November 2019).

In a survey, conducted to assess the situational analysis of mungbean as a catch crop, it was found that half of the farmers use seed brought from open grain market while a

Table 1 Varieties of different grain legumes released during last 5 decades in Pakistan

Crop	Varieties	Type	Yield potential (kg ha^{-1})	Resistance to stresses	Institute/release year
Chickpea					
1	NIAB-CH104	Desi	3819	Wilt and blight	NIAB, Faisalabad/2019
2	Noor-2019	Kabuli	2882	Wilt	AARI, Faisalabad/2019
3	NIAB-CH2016	Desi	3600	Wilt and blight	NIAB, Faisalabad/2016
4	Bittal-2016	Desi	3993	Wilt	AARI, Faisalabad/2016
5	Chattan	Desi	1350	–	GRS, Karak/2015
6	Fakhr E Thal	Desi	1200	–	GRS, Karak/2013
7	Tamman	Kabuli	2200	Drought and wilt	BARI, Chakwal/2013
8	Noor-2013	Kabuli	3282	Wilt	AARI, Faisalabad/2013
9	Bhakkar-2011	Desi	3993	Wilt	AZRI, Bhakkar/2011
10	Punjab Noor-2009	Kabuli	3000	Fusarium wilt	AARI, Faisalabad/2009
11	Punjab-2008	Desi	3400	Fusarium wilt	AARI, Faisalabad/2008
12	CM-2008	Kabuli	3000	Mutant	NIAB, Faisalabad/2008
13	Thal-2006	Desi	2500	Drought and blight	AZRI, Bhakkar/2006
14	Parbat-98	Desi	1500–2000	*Ascochyta blight*	NARC, Islamabad/2003
15	Dashat-98	Desi	1500–2000	*Ascochyta blight*	NARC, Islamabad/2003
16	Karak-2	Desi	2000	Drought tolerant	GRS, Karak/2003
17	Karak 3	Desi	1500–1700	High yielding, Dwarf	GRS, Karak/2003
18	Wanhar-2000	Desi	1600	*Ascochyta blight*	BARI, Chakwal/2001
20	Balkassar-2000	Desi	1600	*Ascochyta blight*	BARI, Chakwal/2000
21	CM-2000	Kabuli	2700	*Ascochyta blight*	NIAB, Faisalabad/2000
22	Punjab-2000	Desi	3300	*Ascochyta blight*	AARI, Faisalabad/2000
23	Hassan-2 K	Kabuli	1900	*Ascochyta blight*	NIFA, Peshawar/2000
24	Lawagar 2000	Kabuli	1500–1600	Drought and wilt	GRS, Karak/2000
25	Sheenghar-2000	Desi	1800	Blight and drought	GRS, Karak/2000
26	KC-98	Kabuli	1500–1600	Blight and drought	GRS, Karak/1998
27	Bittle-98	Desi	2500	*Ascochyta blight*	AARI, Faisalabad/1998
28	CM-98	Desi	2700	*Ascochyta blight*	NIAB, Faisalabad/1998
29	NIFA-2005	Desi	2000	*Ascochyta blight*	NIFA, Peshawar/1996
30	NIFA-95	Desi	2100	*Ascochyta blight*	NIFA, Peshawar/1996
31	CM-88	Desi	3100	Wilt and blight	NIAB, Faisalabad/1994
32	Noor-91	Kabuli	2500	*Ascochyta blight*	AARI, Faisalabad/1992
33	Punjab-1	kabuli	1400	–-	AARI, Faisalabad
34	Punjab-91	Desi	3300	*Ascochyta blight*	AARI, Faisalabad/1991
35	Paidar-91	Desi	3400	*Ascochyta blight*	AARI, Faisalabad/1991
36	NIFA-88	Desi	2000	*Ascochyta blight*	NIFA, Peshawar/1990
37	Karak-1	Desi		Blight	GRS, Karak/1992
38	DG-89	Desi	1500–1600	Root diseases	RRI, Dokri, Sindh/1989
39	DG-92	Kabuli	1500–1600	suitable for rice-based system	RRI, Dokri, Sindh/1989
40	KC-1	Desi	1700–1800	Dwarf	ARS, Kark/1998
41	CM-72	Desi	3000	*Ascochyta blight*	NIAB, Faisalabad/1983
42	C-44	Desi	3000	*Ascochyta blight*	AARI, Faisalabad/1983
43	C-727	Desi	2200	Drought	AARI, Faisalabad/1964
44	C-612	Desi	1850	Disease	AARI, Faisalabad/1952
Lentil					
1	Punjab Masoor2020		2925	Wilt, rust and grey mold	AARI,and NIAB Faisalabad/2019
2	Punjab Masoor 2018		2529	Rust and grey mold	AARI, Faisalabad/2018
3	Chakwal Masoor		2694	Drought	BARI, Chakwal/2011
4	Punjab Masoor-2009		2800	Rust, stem rot and lodging	AARI, Faisalabad/2009
5	Markaz-09		3200	Drought and lodging	NARC, Islamabad/2009

Table 1 (continued)

Crop	Varieties	Type	Yield potential (kg ha^{-1})	Resistance to stresses	Institute/release year
6	NIAB-Masoor-2006		2500	Mutant	NIAB, Faisalabad/2006
7	NIA Masoor-05		2956	Rust and blight diseases	NIA, Tandojam/2005
8	RK-2004			Drought, spotted testa, microsprema	ARI, D.I. Khan/2004
9	Masoor-2004			Fit for rice-based system, spotted testa, microsprema	ARI, D.I. Khan/2004
10	NIAB-Masoor-2002		2400	*Ascochyta lentis*	NIAB, Faisalabad/2002
11	Shiraz-96		1637	Fusarium. *Ascochyta blight*, cold and drought	AZRC, PARC, Quetta/1996
12	Masoor-93		2600	*Ascochyta blight* and rust	AARI, Faisalabad/1991
13	Mansehra-89			*Ascochyta blight* and rust	ARS, Dhudial, NWFP/1989
14	Masoor 85		2250	*Ascochyta blight*, rust and collar rot	AARI, Faisalabad/1985
Mungbean					
1	PRI Mung-2018		2119	Yellow mosaic virus, and grey mold	AARI, Faisalabad/2018
2	NIFA-Mung-2019		2000	Yellow mosaic virus	NIFA, Peshawar/2019
3	6601		–	High yielding	AARI, Faisalabad/1971
4	AZRI-Mung-2018		2500	Yellow mosaic virus	AZRI, Bhakkar/2018
5	NIFA-Mung 2017		2000	Yellow mosaic virus	NIFA, Peshawar/2017
6	NIAB Mung 2016		2700	Yellow mosaic virus	NIAB, Faisalabad/2016
7	NIAB Mung 2011		2500	Yellow mosaic virus	NIAB, Faisalabad/2011
8	Dera Mung		–	Yellow mosaic virus, charcoal rot and leaf crinkle virus	PARC Pulses Prog. ARI, D.I.Khan/2008
9	AZRI Mung-06		2000	Disease and heat	AZRI, Bhakkar/2006
10	Chakwal Mung-2006		2006	Drought, yellow mosaic virus, bean yellow mosaic virus, and urdbean leaf crinkle virus	BARI, Chakwal/2006
11	NM-2006		3000	Yellow mosaic virus	NIAB, Faisalabad/2006
12	Ramzan-2005		2000	Drought and yellow mosaic virus	NIFA, Peshawar/2005
13	Karak Mung-1		600	Blight	ARS, Karak
14	NM-98		2500	Yellow mosaic	NIAB, Faisalabad/1998
15	Chakwal M-6		1600	Diseases	BARI, Chakwal/1998
16	Chakwal Mung-97		1200	Cercospora leaf spot and yellow mosaic virus	BARI, Chakwal/1997
17	AEM-96		1800	Cercospora leaf spot and yellow mosaic virus	NIA, Tandojam/1998
18	NM-92		2650	Cercospora leaf spot and yellow mosaic virus	NIAB, Faisalabad/1996
19	NM-54		2500	Cercospora leaf spot	NIAB, Faisalabad/1990
20	NM-51		2450	Cercospora leaf spot	NIAB, Faisalabad/1990
21	NM-20–21		2200	—	NIAB, Faisalabad/1986
22	NM-121–25		2150	—	NIAB, Faisalabad/1986
23	NM-19–19		2200	—	NIAB, Faisalabad/1986
24	NM-13–1		2100	—	NIAB, Faisalabad/1986
25	NM-28		1900	—	NIAB, Faisalabad/1983
Mashbean					
1	BARANI Mash		1743	Mosaic and leaf spot	BARI, Chakwal 2018
2	Arooj-2011		1900	Yellow mosaic virus and urdbean leaf crinkle virus	AARI, Faisalabad/2011
3	Chakwal Mash		1600	Diseases	BARI, Chakwal 2000
4	Chakwal Mash-97			Yellow mosaic virus	BARI, Chakwal/1997
5	Mash-97		1700	Yellow mosaic virus	AARI, Faisalabad/1997
6	Mash-3		1000—1500	Yellow mosaic virus	NARC, Islamabad/1993

Table 1 (continued)

Crop	Varieties	Type	Yield potential (kg ha^{-1})	Resistance to stresses	Institute/release year
7	Mash-2		1500—2000	Yellow mosaic virus	NARC, Islamabad/1993
8	Mash-1		1500—2000	Yellow mosaic virus	NARC, Islamabad/1993
9	Mash-88		1800	Disease	AARI, Faisalabad/1988

NIAB Nuclear Institute of Agriculture and Biology, *AARI* Ayub Agriculture Research Institute, *BARI* Barani Agricultural Research Institute, *AZRI* Arid Zone Research Institute, *NARC* National Agricultural Research Centre, *NIFA* Nuclear Institute for Food and Agriculture, *NIA* Nuclear Institute of Agriculture, *D.I.Khan* Dera Ismail Khan, *ARS* Agriculture Research Station, *ARI* Agriculture Research Institute, *PARC* Pakistan Agricultural Research Council, *RRI* Rice Research Institute

Source: https://www.parc.gov.pk, Accessed 28 October 2019; https://www.niab.org.pk/mutation, Accessed 28 October 2019; https://aari.punjab.gov.pk, Accessed 05 November 2019

quarter uses previously saved seed. Only 2% of farmers use registered dealers or companies' seed (Rani et al. 2018). Another survey indicated that 85% of chickpea growers use their seed taken from the previous crop (Shah et al. 2007), which results in low productivity. The major problems, in crop improvements, include inadequate breeding programs and quality seed production, multiplication and distribution systems. The seed corporations and companies do not produce and market the seed of pulses rather their major focus is on cereals and cotton. Other reasons include failure of the public sector to supply good quality source seed, lack of interest of private sector in seed production and distribution, poor institutional support to the private sector in quality seed production and supply. However, in the ACIAR-project to enhance the production of pulses, the pulses growers are being linked with the private organizations and non-government organizations (NGOs) for the procurement of quality seed. These private entrepreneurs purchase the produce of farmers and store the seed for the next growing season. In this project, farmers are also encouraged to store the seeds to participate in the local seed banks (https://aciar.gov.au, Accessed 15 November 2019).

Abiotic Stresses

Drought Stress

Pulses production is threatened by various abiotic stresses. Among these stresses, drought is the most devastating. Global climate models have predicted an increase in the frequency and intensity of drought stress (Rosenzweig and Colls 2005) in the future. In arid and semi-arid tropics, water scarcity is the major constraint limiting grain legumes production (Farooq et al. 2017a). Drought stress in chickpea reduced growth, photosynthesis, and photosystem-II efficiency (Ullah et al. 2019a).

Although pulses need a very low amount of water, but water deficit during critical stages of crop growth causes a significant reduction in yield formation. Although chickpea is a relatively drought tolerant crop among the pulses, this requires enough moisture at critical growth stages viz. planting and at flowering/pod formation. Likewise, lentil also requires adequate moisture at planting and pod formation stage. Mungbean and mashbean, being summer pulses, need at least 4–5 irrigations during the crop growth cycle, however, flowering and pod formation stages are the most critical. Although drought at any stage of pulses may affect its growth and yield formation, however, this is more devastating when it occurs at reproductive and grain development stages and may result in complete crop failure (Farooq et al. 2017a).

Under terminal drought stress, a reduction in grain yield of chickpea is reported from 42 to 70% (Leport et al. 1998). Drought stress at the flowering and reproductive stages in mashbean causes yield reduction of 31–57% (Baroowa and Gogoi 2014) and 26% (Baroowa and Gogoi 2013), respectively. At the end of growing season chickpea and lentil frequently suffer from drought stress; moreover, under rain-fed conditions at pod and seed setting drought is accompanied by heat stress (Sabaghpour 2004).

The low moisture availability is also another factor that drastically decreased pulses yield as are grown under rain-fed conditions in Pakistan. In rainfed areas, the success and production of crop depend on the rainfall. In Pakistan, under rainfed conditions, there are no artificial irrigation systems to irrigate pulses at critical growth stages (e.g. germination/stand establishment and flowering/pod formation). Moreover, at the germination stage (late October to mid-November) the temperature is usually high, and the reserve moisture is lost through evaporation which negatively influenced the stand establishment and ultimately the yield. Furthermore, during flowering (end of February–mid-March) the temperature increases which triggers loss of moisture and results in flower abortion and yield reduction (Personnel observation).

Under low moisture, the nitrogen fixation is badly reduced as in dry soil rhizobia population drastically reduced (Giller and Wilson 1991a, b). In low rainfall areas, chickpea does not show its full potential although it sets seed under warmer conditions compared to all other pulses. The cool wet environment stimulates foliar diseases in chickpea and adversely affects the seed set and yield.

High Temperature

Global climate models have predicted an increase of 4 °C by the end of this century (IPCC 2013), and an increase in the severity and frequency of heat waves (Pittock 2003). Heat stress during grain–filling and reproductive development, in winter pulses, may also cause substantial yield reduction (Farooq et al. 2017b). For instance, the threshold temperature for the reproductive growth stage in chickpea is 25 °C. Likewise, the threshold temperature for flowering and pod development in mungbean ranges from 10 to 30 °C (Farooq et al. 2017b). Any increase in temperature beyond this threshold may cause yield reduction. In chickpea, high temperature (35/30 °C) at seedling stage significantly decreased the photosystem-II efficiency, photosynthesis, and growth of chickpea (Ullah et al. 2019a). Heat stress suppresses the growth of pulses during stand establishment, vegetative, and reproductive growth stage. Heat stress at stand establishment stages affects the seedling germination and reduces seedling survival. However, heat stress at reproductive stage reduces the number and weight of grains and may even cause grain abortion (Farooq et al. 2017b).

An increase in soil temperature above (50 °C) kills the soil bacteria even those which are in symbiosis with pulses (Giller and Wilson 1991a, b). High temperature harm seed germination/emergence, seed vigor, and seedling survival (Wahid et al. 2007), as recorded in various pulses, chickpea (Kaushal et al. 2011; Piramila et al. 2012), alfalfa (Mingpeng et al. 2010) and mungbean (Kumar et al. 2011). The high temperature of 50 °C for 2 h in mungbean causes damage to seedlings in terms of mean seedling germination, growth and heat tolerance index (Mansoor and Naqvi 2012) and 35–50 °C for 4 h in lentil (Chakraborty and Pradhan 2011).

High temperature negatively affected the pulses at both the stand establishment and reproductive stage. At stand establishment, the increase in temperature decrease the seedling germination/seedling vigor and seedling survival. At the reproductive stage, the increase in temperature reduced seed size and seed development.

Chilling Stress

Above freezing low temperature (0–15 °C) is defined as chilling stress. Like heat stress, chilling stress also affects the vegetative and reproductive growth of pulses. Generally, plants of tropical and subtropical origins are sensitive to chilling temperature (0–10 °C) and are incapable of cold acclimation (Adam and Murthy 2014). Chilling stress during germination and seedling emergence stages significantly reduces the stand establishment as reported by Farooq et al. (2017c) that chilling stress of 13/10 °C suppressed the stand establishment and growth of chickpea. Likewise, pulses are highly sensitive to low temperature at flowering and early pod-formation stage (Maqbool et al. 2010; Rana et al. 2016).

Salinity Stress

Salt stress is also one of the major constraints to profitable of pulses in Pakistan. Salt stress affects the germination, growth, and yield formation of crop plants due to osmotic stress, specific ion toxicity and nutrient imbalances (Farooq et al. 2015, 2017d; Khan et al. 2015). In a pot study, Ahmad (2009) reported that salt stress decreased the seed yield per plant due to reduce seed per pod and 100-seed weight.

The accumulation of excessive salts in pulses increased anthocyanin pigmentation in leaves and stems which reduce germination and seedling establishment (Kumar et al. 2016). Salt stress affects the uptake of nitrogen and biological nitrogen fixation (Frechilla et al. 2001; Rabie and Almadini 2005), which further limits the nitrogen supply in grain legumes (Farooq et al. 2017d). In biological nitrogen fixation nodules are affected mainly due to soft structure, for example, nodule density and activity are reduced under salt stress in faba bean (Rabie and Almadini 2005) and pigeonpea (*Cajanus cajan* L.) (Garg and Manchanda 2008) due to premature senescence (Matamoros et al. 1999) which further reduced the biological nitrogen fixation (Delgado et al. 1994).

Salinity stress of 3.8 dS m^{-1} in chickpea causes yield losses up to 72% (van Hoorn et al. 2001). Likewise, salinity stress of 3.1 dS m^{-1} causes 100% yield loss in lentil (van Hoorn et al. 2001), and salinity stress of 250 mM NaCl cause more than 80–100% yield losses in mungbean (Sehrawat et al. 2013).

In Pakistan, the area under salinity is 10 Mha, while data on the saline area under pulses cultivation are not available. As in Pakistan, pulses are grown on marginal lands with low to moderate level of salinity, growth and yield are significantly reduced.

Biotic Stresses

Weeds

Weeds may cause 20–90% yield losses in different pulse crops. These yield losses depend upon the composition and density of weed flora, however, unmanaged weed may even cause complete crop failure. Yield losses due to weeds in chickpea vary between 24 and 63% (Abbas et al. 2016), lentil (20–30%) (Tanveer and Ali 2003), and mungbean (46%) (Mansoor et al. 2004).

Goosefoot (*Chenopodium album* L.) is the major weed of chickpea. Other important weeds of chickpea (and of winter pulses) include onionweed (*Asphodilus tenuifolius* Cav.), nettleleaf goosefoot (*Chenopodium murale* L.), wild safflower (*Carthamus oxyacantha* L.) and grass pea (*Lathyrus sativus* L.). Broomrape (*Orobanche aegyptiaca* Pers.) is an important weed of lentil. Major weeds of mungbean (and of summer pulses) include field bindweed (*Convolvulus arvensis* L.), purple nutsedge (*Cyperus rotundus* L.) and crowfoot grass (*Dactyloctenium aegyptium* L. (Wild).

In Pakistan, selective herbicides for chemical weed control in pulses are not available. However, in the ACIAR-funded project, some pre- and post-emergence herbicides, for weed control in pulses, are being tested (https://aciar.gov.au, Accessed 15 November 2019).

Diseases

Disease infestation causes significant yield losses (4–40%) in different pulse crops (Ali 1982). However, in several cases, complete crop failure has also been noticed. The important diseases of chickpea include ascochyta blight (*Ascochyta rabiei*), fusarium wilt (*Fusarium oxysporum* Schlecht), botrytis gray mold (*Botrytis cinerea* Pers), dry root rot (*Macrophomina bataticola*), phytophthora root rot (*Phytophthora megasperma* Drechsler), and damping-off (*Pythium ultimum* Trow). In 1980–1983, there was severe Ascochyta blight infestation on chickpea in Pakistan. During the period of three years, the disease attack was epidemic and the estimated yield losses were 48–70% (Malik and Bashir 1984). Fusarium wilt may cause up to 75% yield loss in chickpea, dry areas of Pakistan are more prone to this disease (Khan 1979). During the 1950s, 50% of chickpea production was reduced due to wilt damage while in the 1990s it was 10% in irrigated areas of Pakistan (Hanif et al. 1999). Food Legumes Programme at the National Agricultural Research Centre, Islamabad released two high yielding disease resistant varieties (Dasht and Parbat) during 2003 to replace blight susceptible cultivars. After that, several varieties were developed against different diseases which are given in detail in Table 1.

The important lentil diseases include lentil blight (*Ascochyta lentis*), wet root rot (*Rhizoctonia solani*), dry root rot (*Macrophomina phaseolonia*) sclerotial state (*Rhizoctonia bataticola*), vascular wilt (*Fusarium oxysporum* f. sp *lentis*), black root rot (*Fusarium solani*), and pythium root rot (*Pythium ultimum*). The lentil blight caused 30–40% damage to the crop during 1982–1983 (Malik 1983).

The most important diseases of mungbean and mashbean are yellow mosaic (mungbean yellow mosaic virus), cercospora leaf spot (*Pseudocerospora cruenta*) and powdery mildew (*Erysiphe polygoni* and Odidim sp.). The annual yield losses due to disease infestation, in mungbean, are 16–20% (Bashir and Malik 1988).

Insect–Pests

Insect–pests may cause 46–96% yield losses in pulses depending on crop and cultivars. Pod borer (*Helicoverpa armigera*) is one of the most important insect-pests of chickpea. In the northern part of Pakistan, 90% damage of chickpea by pod borer has been reported (Ahmad et al. 1986). Insect-pests of mungbean and mashbean include leaf hopper (*Empoasca kerri* Pruthi), galerucide beetle (*Madurasia obscurella*), whitefly (*Bemisia tabaci* Genn.), and hairy caterpillar (Spilosoma (Diacrisia) ulinar Walker). Whitefly is a vector of a yellow mosaic virus which is the most important disease of mashbean and mungbean. Pod borer and caterpillar are also major insect-pests of mungbean in Pakistan (Rani et al. 2018). Common insect-pest of lentil are aphids (*Aphis craccivora*), pod borer (*Helicoverpa armigera* Hiibner), green bug (*Nezara virudida*) and Bruchids (*Callosobruchus chinensis* L.).

Soil Related Issues

High pH

Pakistani soils are generally alkaline calcareous in nature, having a pH of more than > 8.5; whereas pulses grow well in soils with slightly acidic (6) to slightly basic pH (8.5) (https://grdc.com.au/_data/assets/pdf_file/0011/210350/chapter-1-the-role-of-pulses.pdf.pdf).

Marginal Lands

Pulses are mostly grown on marginal lands where profitable production of other crops is not feasible. The marginal lands are generally degraded soils, which are low in organic matter and are nutrient deficient. For instance, chickpea is grown in rainfed lands of Thal and arid lands of Pothohar (Ullah et al. 2019b, 2020a), which are Zn deficient (FAO 2017).

High temperature changes the soil organic matter, making soil problem more intense, and these changes, in turn, limit the root penetration and development. The organic matter of Pakistani soils is already very low and the growing of pulses on marginal lands further aggravates the situation. The soils which are nutrient deficient, sandy in nature, contain high salt, and have high pH comes under marginal soil or degraded soils. The neglected research on pulses and growing on degraded soils badly reduced the yield of pulses.

In a report on “Land Degradation Assessment in Dryland project” it is estimated that 43% of rangelands and 20% croplands and 33% of soils are degraded globally (Vargas et al. 2016). The low agricultural productivity in rain-fed areas is owing to soil erosion; which depletes soil nutrients in a greater amount (Iqbal and Ahmad 2005; Ali 2010). A common practice for erosion control and moisture retention is stubble retention and pulses fit into such systems. As pulses are grown in sandy or on degraded soil, soil erosion is also a factor in the low yield of pulses in such soils. Growing of pulses as cover crops or stubble retention in such soils decreases the problem of soil erosion to a greater extent and significantly increased the yield owing to improved soil fertility.

Post-harvest Losses

The measurable quantitative and qualitative food loss through the supply chain, starting from harvesting to consuming or end use is called post-harvest loss. Worldwide every year, about 1.3 BT or 1/3rd of the food produced is wasted. A big factor in low yield of pulses is post-harvest losses after the biotic and abiotic factors. The harvesting of pulses in Pakistan is through manual means while in developed countries like Australia and Canada it is through mechanical means. At the time of harvesting, the shortage of labor and machinery is also the main cause of post-harvest losses. For instance, in the case of chickpea, the labor is not available due to harvesting of wheat as chickpea mature 15–20 days earlier than wheat. Sometimes labor is available for harvesting but for threshing, there is no labor availability. Due to delay in threshing, the shattering of grains occurs owing to high temperature (> 35 °C) which causes significant yield losses. Moreover, the threshing of pulses in Pakistan is done with wheat thresher which is usually available after wheat threshing. Similarly, in the case of mungbean the labor and tractors are is usually busy in the preparation of field for rice cultivation (Personnel observation). Likewise, during processing the losses also occurred. According to our limited knowledge, no comprehensive data are available regarding post-harvest losses in Pakistan. In conclusion, post-production saving of food significantly contributes to the sustainability and food security of the world.

Lack of Farm Machinery

Lack of crop-specific farm machinery (for harvesting and threshing) is one of the major reasons of low yield in pulses. Crop-specific planting machinery is also not available to the farmers. Most of the farmers, sow the pulses by broadcast method (Rani et al. 2018). Crops are harvested manually, however, wheat threshers are used for threshing crops, which results in grain breakage and losses with straw.

Climate Change Impacts

Climatic variability and the associated increase of abiotic (extreme high/low temperature, extreme rainfall, and drought stress) and biotic factors (weeds, diseases, and viruses owing to extreme abiotic stresses) negatively reduced the growth and productivity of legumes (Varshney et al. 2011). Pulses are food crops that ensure food security, nutrition, human health, and sustainability of agriculture and help to mitigate and are adaptable to climate change (Caon et al. 2016). Climate change impacts the soil resources by changing the soil water availability (change in quantity and pattern of precipitation), and soil organic carbon decomposition rate (due to high temperature) which in turn impacts the pulses production in drylands.

Lentil genotypes are sensitive to photoperiod and temperature as sowing of lentil in October produce good yield but delay in sowing after October causes a decrease in yield due to reduced vegetative growth. The timely sown crop results in good yield and its components characters (Solanki and Singh 2000). In Pakistan and India, lentil landraces produce flower late and their reproductive development begins when conditions are extremely hot and dry (Erskine and Saxena 1993), and the high temperature reduces the yield of lentil (Erskine 1996). The early flowering exposed crops to a risk of frost damage in some conditions if flowering is early and crop produce inadequate biomass for sustaining large seed yield (Turner et al. 2001).

In many parts of the world, the yield of pulses is low due to an unpredictable climate (Giller and Wilson 1991a, b). Moreover, the occurrence of extreme abiotic stresses supports biotic stresses in pulses as high rainfall which increases diseases and viruses attack. Likewise, too much moisture shortage causes a termite attack in pulses.

Marketing

International trade in pulses has grown rapidly than production. India faced a massive price hike in pulses owing to poor harvest a few years ago (https://www.fao.org/pulses-2016). In a situational analysis survey, it was observed that 86% of farmers sold their pulse grains to a middleman in the village or at an open grain market with an average selling price of US \$ 0.91 kg^{-1} (Rani et al. 2018). The one of the major reasons in the low market price for chickpea in Pakistan is lack of cleanliness (Shah et al. 2007).

Substitution by Major Crops

With the green revolution, the introduction of high yielding varieties of wheat and rice along with improved irrigation facilities have increased the area under their cultivation. Both the rice and wheat are high yielding and less susceptible to the biotic and abiotic factors, have replaced the legumes as legumes are more susceptible than cereals. With the expansion of the rice–wheat cropping system in all parts of the country, the area and productivity under pulses viz., chickpea, pigeonpea and lentil had suffered to a greater extent. Moreover, the substitution of pulses with major crops is also owing to the high yield instability of pulses compared with cereals. For this very low yield of pulses, it is difficult for food legumes to compete with wheat except on rainfed and marginal lands where wheat cannot grow economically. Farmers prefer to grow wheat, due to higher economic returns both in terms of grain and straw.

Opportunities

Crop Improvement

The crop improvements include root architecture, early phenology, flowering, podding, seed set, and dry matter production which are associated with a better yield of grain legumes. The early phenology with rapid ground cover and dry matter production allows efficient use of water in post-flowering period (Siddique et al. 2001) and protect from the impact of abiotic stresses. Next-generation sequencing has improved breeding in legumes as in chickpea (Varshney 2016), however; the rate of improvement is low as compared to cereal crops. With the present rate of crop improvement in legumes, crop yield will remain insufficient to feed the world population by 2050 (Godfray et al. 2010).

Under drought conditions, the yield is strongly linked with early vigour and pod set which enables the plants to escape drought (Leport et al. 2003). The time of flowering is important as it defines the duration of the vegetative phase, and at the same time determines the climatic conditions to which crop is exposed during the reproductive stage (Lawn et al. 1995). To meet the ever-increasing need of grain legumes for the next generation and to develop climate resilient genotypes of pulses crop improvement is an inevitable option. There is a need to develop new genotypes with a focus on root system (deep rooted and a greater number of root hairs), early phenology, more dry matter accumulation, early maturing and resistance to diseases and insect-pests.

Intercropping

Growing more than one crop at the same time in the same field in definite rows or a staggered manner is called intercropping. Pulse crops can utilize a greater amount of water stored in the profile and can stand drought better than shallow rooted crops owing to deeper and more profuse root systems (Caon et al. 2016). The deep tap root system and slow initial growth of pulses makes them more suitable for intercropping with cereals and oilseeds under rainfed conditions (Ali and Venkatesh 2009), and the reproductive growth of these intercrops does not coincide with that of the main crop and the yield of main crops is not affected adversely (Singh et al. 2008). The leguminous crops like black bean, cowpea, mungbean and pigeonpea can be sown in-between the cereal like wheat, mustard (*Brassica juncea* L.), maize (*Zea mays* L.), pearl millet [*Pennisetum glaucum* (L.) R.Br.] and vegetables (FAO 2013).

Green gram is intercropped in kharif season with maize, pearl millet, pigeonpea, sesame (*Sesamum indicum* L.), and cotton (Swaminathan et al. 2012). In spring planted sugarcane, green gram is also grown as an intercrop (Swaminathan et al. 2012). In India, more than 70% area is under intercropping. In the rainfed areas of India, winter pulses chickpea and lentil are commonly intercropped with oil seeds. Chickpea is also grown with wheat and barley (*Hordeum vulgare* L.) under rainfed conditions (https://vikaspedia.in/agriculture/crop-production/package-of-practices/pulses/cropping-systems-involving-pulses). The co-cropping of wheat and chickpea improved the nutrient utilization (nitrogen and phosphorus), crop yield, and income than monoculture wheat and chickpea (Akhtar et al. 2010).

In our cropping system, the winter legumes as chickpea and lentil can be successfully intercropped in wheat and sugarcane. In the case of summer legumes, mungbean can be intercropped with sesame. The examples of yield benefits in different crops due to intercropping of pulses are shown in Table 2.

Use of Pulses as Catch Crop

Catch crop is a short duration crop which is grown in between the main crops. Pulses are grown as catch crops in between two cereal crops (Reddy et al. 2013). Summer or spring mungbean is grown as a catch crop (Swaminathan et al. 2012). The one way to include pulses in the rice–wheat

Table 2 Yield improvement of cereals with the inclusion of pulses as intercrop

Intercropping system		Grain yield of main crop (t ha^{-1})		Increase in yield (%)	References
Main crop	Intercrop	Sole	Intercropping		
Rice	Cowpea	4.02	5.08	26	Abdul et al. (2010)
Rice	Sesbania	4.02	4.92	22	Abdul et al. (2010)
Wheat	Chickpea (1:1)	1.51	1.72	14	Khan et al. (2005)
Wheat	Chickpea (2:1)	1.51	1.67	11	Khan et al. (2005)

"(:)" indicates ratio between the rows of main crop and the intercrop cropping system without affecting the area of these crops is to grow pulses as a catch crop. The short duration (60–70 days) and extra short duration pulses (45–50 days) as mungbean can be used as a catch crop between wheat and rice (Ram et al. 2013). Mungbean is an early maturing grain legume that can be grown as a catch crop in wheat and rice systems of South and Central Asia (Rani et al. 2018). The early maturing mungbean varieties which are harvested in 60 days and are resistant to diseases have been adopted on a large scale in South Asia (Shanmugasundaram et al. 2009). In case of Pakistan, the short duration mungbean varieties (55–70 days) improves the productivity of rice–wheat cropping systems as reported that growing of mungbean as catch crop in between the rice–wheat improved grain yield of wheat by 21% and grain nitrogen uptake (29%) (Yaqub et al. 2010). For example, higher rice yield was harvested after inclusion of mungbean in the rice–wheat cropping system (Singh and Sharma 2001). In another study, Singh et al. (2011), reported that the inclusion of mungbean into rice–wheat cropping systems enhances total productivity and net returns. Another study reported that the incorporation of summer mungbean biomass in the soil after picking of pods not only improves the yield but also decreases the nitrogen fertilizer demand of rice up to 25% (Ram et al. 2013).

Conservation Agriculture

Conservation agriculture based on three principals which are (i) minimal soil disturbance, (ii) permanent soil cover, and (iii) crop rotations (Hobbs et al. 2008). The warming due to climate change induced changes in soil, water, and temperature (increase soil organic carbon decomposition rate) and increase the soil erosion risks and desertification which further have feedback on climate change (Caon et al. 2016) and impact of climate change is more severe in drylands due to bareness of soil. Degraded soils limit the ecosystem services which support life on earth and human well-being (Caon et al. 2016). Therefore, it is needed to adapt conservation agriculture in drylands to avoid the unbearable losses. The degraded soils can be restored by keeping the soil surface covered, improving the crop selection and crop rotation, and by practicing the conservation tillage (Caon et al. 2016).

Conservation agriculture based on resource-saving technologies provide a good opportunity to increase pulses production owing to area expansion and productivity improvement due to timely crop establishment, better utilization of natural resources, increase input use efficiency, system diversification, saving of external inputs and reduction in the cost of cultivation (Abrol et al. 2005). Inclusion of pulses with resource conservation technologies provides the opportunity of diversification as rice-pulses production system after rice-fallows, saves water, and better utilizes it (Ram et al. 2013). The pulse-based cropping systems are environmentally sustainable owing to the lower use of fertilizers, pesticides, and irrigation (Reddy 2004, 2009).

Pulses contribute to soil health through biological nitrogen fixation, and solubilization of phosphorus ions from calcium and iron phosphate, besides this, these also increase the soil organic matter, soil structure and maintain the soil biodiversity (Caon et al. 2016) as low soil organic matter cause low yield of pulses. Moreover, by adopting the practice of conservation agriculture the major abiotic issues (as low moisture/drought, and high temperature impacts), biotic problem (as weeds infestation, disease, and insect-pests) and soil-related (as low organic matter, and degraded lands) and climate change impacts can be minimized along with yield benefits.

Thal desert (which covers districts Jhang, Bakhar, Khushab, Mianwali, and Layyah) of the country has a great potential for the adoption of conservation agriculture as this region remains fallow after the harvesting of chickpea. In some areas of this region only pearl millet [*Pennisetum glaucum* (L.) R.Br.] and guar [*Cyamopsis tetragonolobus* (L.) Taub] are grown in summer while rest remain fallow. Furthermore, in some parts of the Barani region as Attack and Rawalpindi, this can also be adopted.

Seed Distribution System

The seed is a basic input to get something from a piece of land. The 20–25% increase in crop yield can be attained with the use of quality seed (Ram et al. 2013). To increase the production of low-cost innovative seed systems and farmers' preferred varieties through farmers' participatory varietal selection should be provided (Reddy et al. 2013). In many countries, there are established seed grower associations to develop the quality seed of chickpea (Monyo and Varshney 2016). By using similar approaches, seed production and distribution can be improved in Pakistan as well. Need for seed for the sowing of pulses in the country is almost 43, 000 metric tons while the total availability is 1400 metric tons (www.federalseed.gov.pk, Accessed 01 January 2020).

Seed a basic input in crop production, and to ensure timely availability of quality seed, seed production should be enhanced with the involvement of government, public–private partnerships, and NGOs. The participation of seed growers in seed production should be encouraged through the registration process. Seed distribution can be managed with the help of co-operative which takes breeder seed and multiplied them by involving contract farmers to produce quality seed for maximum dissemination.

Marketing and Support Price

To increase the production of pulses; stable prices for a longer period through innovative market interventions, stable market infrastructure, price information systems, and enhanced credit availability in pulses growing districts are needed. To increase the area under pulses production in Pakistan, there should be a support price mechanism and infrastructure for pulses to attract farmers, as there is a support price and marketing system in cereal and fiber crops.

Farm Machinery for Pulses

Farm machinery is a major factor in the success and adoption of crops. The 100% success of a cop depends upon its machinery. Improvement in awareness regarding utility of wider adaption of farm machinery, herbicides, micro-irrigation facilities to cope with the labor and water shortages should be provided (Reddy et al. 2013) to promote and get maximum yield of pulses. The provision of incentives for the adoption of low-cost technologies such as the application of micronutrients should be ensured for an increase in production (Reddy et al. 2013). The adoption of farm mechanization can be improved by developing varieties suitable for harvesting with combine harvesters (Reddy et al. 2013).

To increase the area and production of pulses in the country, there is a need to import machinery and then local reverse engineering of this machinery should be done. By adopting these means the area and yield of pulses can be significantly improved. In conclusion, the provision of this farm machinery on a subsidized basis can help to get farmers' interest in growing pulses.

Development and Dissemination of Site-Specific Package of Production Technologies

To enhance the legume production there is need to develop and disseminate low-cost production technologies in pulses as (i) low cost innovative seed systems and selection of farmers' preferred varieties through farmer's participatory varietal selection to replace the old low yielding varieties (Reddy et al. 2013), (ii) provision of incentives for adoption of low cost technologies such as application of micronutrients to decrease the cost of production and increase yield, (iii) creation of awareness about the utility of wider adaptation of farm machinery, herbicides and micro-irrigation facilities to cope with labor and water storage (Redyy et al. 2013). The better identified technologies need to be subsidized for wider adoption (Reddy et al. 2013).

Moreover, there is a need to develop technologies with a focus on the sowing method, weed, and nutrient management. In the sowing method, planting geometry is a good option while for weed and nutrient management the integrated management of the same can help to improve the situation of pulses in the country. Integrated approaches of weed and nutrient management are very successful as reported in a study of integrated weed management in chickpea under rainfed conditions found that pendimethalin 38% CS + hand weeding at 30–35 days after sowing (DAS) and pendimethalin 30% EC + imazethapyr 2% + one hoeing at 30–35 DAS recorded the highest grain yields (1.19 t ha^{-1}), net returns (US$341 ha^{-1}) and benefit:cost ratios (2.10), lowest weed dry weights (11.3 g m^{-2}) and highest weed control efficiency (83%) relative to the other integrated treatments (Rathod et al. 2017). Similarly, in a study of integrated nutrient management (INM) in chickpea, INM [farmyard manure/poultry manure (20 t ha^{-1}) + NPK (18–36-10 kg ha^{-1})] increased total pod number per plant (66), seed yield (1.58 t ha^{-1}) and total OM (1.29%), relative to the sole application of NPK or organic manure (Sohu et al. 2015). By adopting these integrated approaches, the production of pulses can be increased in the country as well.

In a survey, it was found that 70% of growers have complete knowledge about critical stages of irrigation, 38.33% know the recommended method of sowing, 30% have information regarding recommended spacing, 10% have seed treatment and insect pest and diseases knowledge respectively (Shakya et al. 2016). Knowledge about soil treatment, high yielding varieties, and biofertilizers was poor. It was also found that 80% of the farmers have a medium level of information regarding chickpea production technology; only 18% have a high level of knowledge (Shakya et al. 2016).

The site-specific production technologies exist as growing of pulses after rice fallow. For example, minimum/zero tillage after rice in uplands gives better yield in mungbean and cowpea compared to intensive high tillage. For the success of a crop, the provision of its production technology is as important as the farm machinery. The production package of pulses should be according to the site, soil, and climatic factors. The awareness regarding the production technologies of pulses should be delivered to farmers through audio, video aids to get maximum production, and to be self-sufficient in pulses requirement.

Seed Enhancements

The seed is the center of crop production, human nutrition, and food security (Finch-Savage and Bassel 2015). Seed enhancement includes those treatments which are employed to seed to improve their performance (under both optimal and sub-optimal environments) after harvesting. The seed treatments are used to improve germination and seedling growth by changing the seed vigor and physiological state of seeds. The seed enhancement techniques include seed priming, seed coating/seed pelleting. Seed priming is a pre-sowing treatment of seeds in water or in an osmotic solution that permits the metabolic activities to occur without radicle protrusion. Seed coating/pelleting is defined as the application of liquid or solid of any substance on the surface of seed as coating.

Priming of seed ensures the initial water/nutrient requirement of the seeds (100% germination/emergence) which is a major problem of low yield in pulses owing to no/low moisture in the rainfed environment. By using this seed priming approach, the initial seed water/nutrient requirement can be fulfilled, and the required number of plant population can be maintained. For example, in our latest studies, we found that seed priming of chickpea seeds of both types in 0.001 M Zn solution improved the germination/emergence, seedling growth, and tissue Zn concentration (Ullah et al. 2019c, d, 2020b). Nutrient priming of soybean seed improved the seed quality for early seedling development of soybean under nutrient limited environment (Imran et al. 2017). Seed priming is most effective in grain legumes, as the soaking of seeds significantly increases the yield in several studies (Musa et al. 2001; Rashid et al. 2004; Harris et al. 2005; Ullah et al. 2019d, 2020b, 2020c). The hydro and osmopriming of the mungbean (*Vigna radiate* L.) seeds significantly increased the seed yield (713–948 kg ha^{-1}) and dry matter yield (4001–5262 kg ha^{-1}) compared to control (Umair et al. 2011). In another study, it was found that osmopriming of mashbean seeds with $CaCl_2$ improved the early stand establishment and seedling growth of mashbean (Minhas et al. 2017).

In Pakistan, mostly pulses are grown on marginal lands where the deficiency of nutrients is a major obstacle in getting required production. To overcome this problem, seed coating is a promising option as in seed coating nutrients are adhered to the surface of seed and become available to the plants when there is moisture availability. For instance, in our latest study, it was found that seed coating of chickpea with 5 mg Zn kg^{-1} seed enhanced the chickpea emergence/germination, seedling root and shoot length and dry weight of chickpea (Ullah et al. 2019b). In a field study, it was reported that application of Zn through seed coating at 5 mg kg^{-1} seed improved the nodulation, grain yield (44%), profitability ($ 1517 ha^{-1}) and grain quality of kabuli chickpea compared to control (no Zn application) (Ullah et al. 2019d). The increase in yield, profit, and benefit–cost ratio due to seed enhancement in different pulses is given in Table 3. In conclusion, seed enhancement improves the germination/stand establishment, growth, yield, and quality of the grain produced.

Conclusion

Pulses are nature's gifted crops that contributes to food security, nutrition, human health, transform agriculture to more sustainable, and help to mitigate climate change impacts by natural adaptations to climate change and improves soil health and fertility by symbiotic nitrogen fixation. In Pakistan, the production of pulses is very low due to neglected attention compared to cereals. Moreover, the other factors which contribute to low production are use of low-quality seed (mostly farmers' own saved), grown on marginal or rainfed conditions, climate change and substitution with cereals. The production of pulses can be increased by the crop improvement as the climate is changing there should be genotypes that are tolerant against biotic and abiotic factors. There should be good quality seed production packages according to the sites/climate and distribution of seed (by Govt. institutes, public–private partnership & NGOs) as more than 80% pulses in Pakistan are grown by the farmers' own saved seed which is poor in quality owing to poor handling and storage conditions. Mostly pulses are grown in marginal soils or rainfed conditions, where germination and stand establishment is a major issue, which can be overcome through seed enhancement (priming, coating/pelleting). The seed enhancement not only improved the germination, growth, and yield but also enhanced the quality of grains. The other ways to increase yield include intercropping and the use of pulses as catch crops. The short duration pulses (as mungbean and green gram) can be intercropped in between the major cereal crops. The unavailability of farm machinery is also a big obstacle in increasing the area and production of pulses in Pakistan. Broadcasting is the major sowing method in most of the areas, only a few areas are sown by drill method. The application of pesticides, insecticides, and harvesting is through manual means. The provision of drills, tractor mounted sprayers and mechanical harvesting can significantly boost production. Furthermore, strengthening of marketing system with support prices can be a boost to increase pulses production.

Table 3 Influence of seed enhancements on yield improvement in pulses under field conditions

Seed enhancement		Crop	Increase in yield (%)	Cost of priming ($ ha^{-1})	Increase in income over control ($ ha^{-1})	Benefit–cost ratio	References
Type	Priming/coating agent						
Seed priming	Hydropriming	Mungbean	11.6	02.0	54.1	1:1.25	Haider et al. (2020)
Seed priming	$ZnSO_4{\cdot}7H_2O$ (0.01 M)	Mungbean	26.9	4.40	177	1:1.35	Haider et al. (2020)
Seed priming	$ZnSO_4{\cdot}7H_2O$ (0.001 M)	Chickpea (Kabuli)	25.0	02.2	340	1:3.73	Ullah et al. (2019c)
Seed priming	$ZnSO_4{\cdot}7H_2O$ (0.001 M)	Chickpea (Desi)	24.3	02.2	321	1:3.55	Ullah et al. (2020b)
Seed priming	$ZnSO_4{\cdot}7H_2O$ (0.001 M) + bacteria	Chickpea (Desi)	24.9	7.76	336	1:3.68	Ullah et al. (2020b)
Seed priming	$ZnSO_4{\cdot}7H_2O$ (0.05%)	Chickpea	19.0	12.6	504	1:39.9	Harris et al. (2008)
Seed priming	PEG-8000	Mungbean	16.1	–	–	–	Khan et al. (2008)
Seed priming	PEG-8000	Mungbean	07.9	–	–	–	Khan et al. (2008)
Seed priming	$ZnSO_4{\cdot}7H_2O$ (0.05%)	Chickpea	36.0	12.9	1282	1:92.0	Arif et al. (2007)
Seed priming	$ZnSO_4{\cdot}7H_2O$ (0.075%)	Chickpea	05.0	13.7	122	1:8.9	Arif et al. (2007)
Seed priming	Humic acid (2%)	Mungbean	42.1	03.7	335	1:89.4	Waqas et al. (2014)
Seed priming	PEG-8000	Soybean	12.9	–	–	–	Arif et al. (2008)
Seed priming	Water	Mungbean	415	11.5	416	1:36.4	Rashid et al. (2004)
Seed coating	$ZnSO_4{\cdot}7H_2O$ (5 mg kg^{-1})	Chickpea (Kabuli)	44.0	02.8	564	1:4.20	Ullah et al. (2019c)
Seed coating	$ZnSO_4{\cdot}7H_2O$ (5 mg kg^{-1})	Chickpea (Desi)	40.3	02.8	529	1:3.99	Ullah et al. (2020b)
Seed coating	$ZnSO_4{\cdot}7H_2O$ (5 mg kg^{-1}) + bacteria	Chickpea (Desi)	37.8	7.35	512	1:4.04	Ullah et al. (2020b)

– not available

Acknowledgements We are thankful to the Pakistan Bureau of Statistics for providing data on pulses import.

Compliance with Ethical Standards

Conflict of Interest Authors have no conflict of interest.

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